DOE BNL HEP Program review : Superconducting Magnet Division

Mission

FY03 Program

LHC Construction Project

Future Activities *

Budget

Issues/ Summary

* Details in the breakout sessions

Brookhaven Superconducting Magnet Division - Mission

- The output of the Superconducting Magnet Division is various superconducting magnets for use in both particle accelerators and experimental facilities. We:
  - work within the U.S. HENP community on future facilities and technologies.
  - collaborate with other science institutions world wide to both provide and develop superconducting magnet technologies.
  - support the ongoing Brookhaven research program with emphasis on the RHIC complex.

- Capabilities include:
  - Superconductor materials development/test facility
  - Magnetic structure analysis and design
  - Superconducting magnet fabrication
  - Vertical and horizontal cryogenic testing
  - Magnetic field measurements

FY03 Magnet Division Program

In addition to the US LHC Project we have HEP activities in the superconductor test facility, materials development, high field magnet development, and linear collider final focus R&D.

- International: LHC (CERN), BEPC II (China), DESY (Germany), GSI (Germany), J-PARC (Japan)
- National: Next generation Magnet R&D, Superconductor Test Facility & Materials development, Linear Collider R&D
- RHIC: e-cooling solenoid system, AGS Snake, Ops support
- Non accelerator: Undulators, Bio-med "rat-tracking" NMR, High field NMR.

FY03 HEP Program Support - Magnet Division

In FY02 we received:

LHC baseline construction funding $7.8M
LHC Accelerator research Program $100K
Superconductor Test Facility and materials development $810K
Magnet R&D $200K (in May)
TOTAL $8.9M

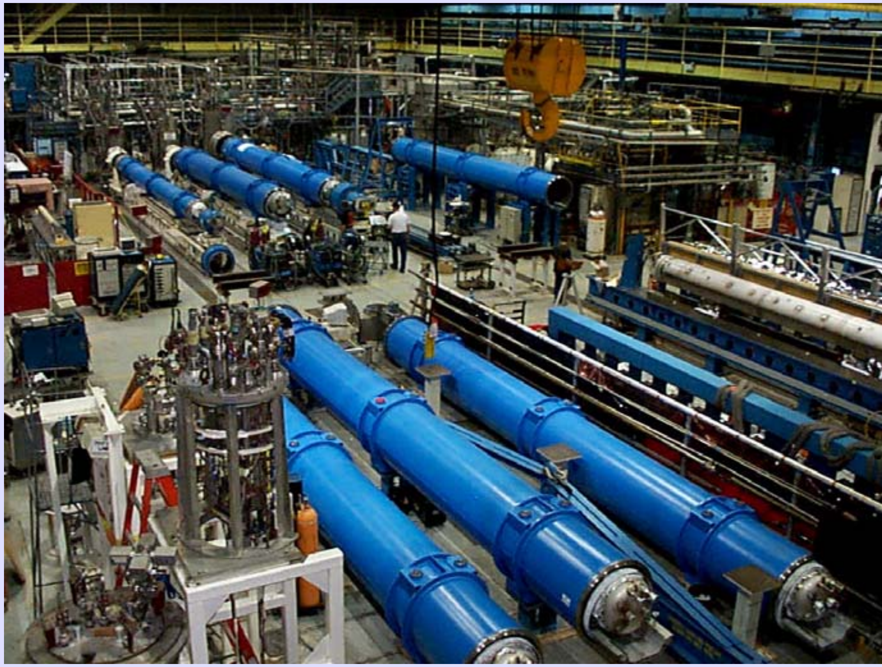
In FY03 we received:

LHC Construction (as per baseline) $3.3M (FY04 $1.3M, FY05 $1.2M)
LHC Accelerator Research Program $100K (expect +$150K)
Superconductor Test Facility and materials development $690K
Magnet R&D $300K
Linear Collider Final Focus development $0
TOTAL $4.4M

Magnet Division Staff reduced by 10 FTE's (10%) in October 02 to 89 FTE's

BNL LHC Magnet Production Status

- D1 production & testing complete (5); 2 shipped.
- D2: production complete (9), 4 tested, 2 QQS' complete
- D4 collaring complete (3), 1st cold mass assembly started
- D3 coils complete (3), collaring to start shortly
- Design effort nearly complete. Remaining items:
  - D3 top level magnet assembly drawing:
    - 1 MM design time remains
    - 1 MM checking
  - D1 interconnect to DFBX in design:
    - Check print corrections (~0.5 MM)
    - 0.5MM checking
- Design issues since last time:
  - CERN-directed QQS changes (2)
  - Lack of guidance on D3 interface (still no formal approval)
  - CERN directed aperture spacing change for D4 and D3



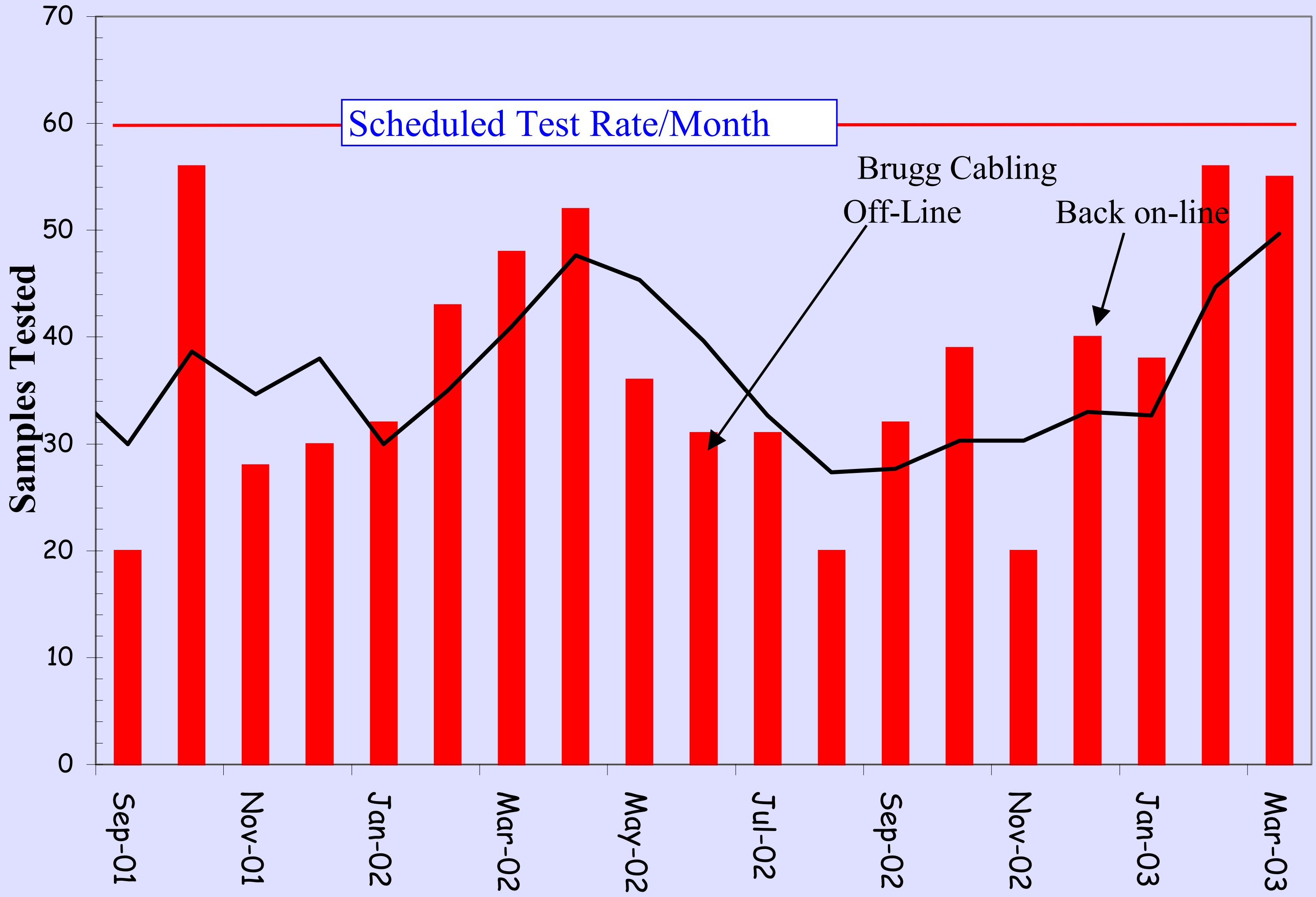
BNL LHC Magnet Production Status (cont'd)

- Issues
  - Last minute CERN directed rework to D4 beam tubes, end plates, end volumes, for aperture spacing change
    - 2 month delay
  - D4 yoke lamination delivery delays
    - 1 month delay (beyond beam tubes)
    - Deliveries have since begun; complete by end Feb03
  - Significant Scientific, EDIA, technician labor overrun associated with magnet acceptance:
    - Survey & repositioning of D1 He pipes (not to be repeated for D2)
    - Compilation, revision, submittal of paperwork to CERN
    - Warm-to-cold magnetic measurement issues

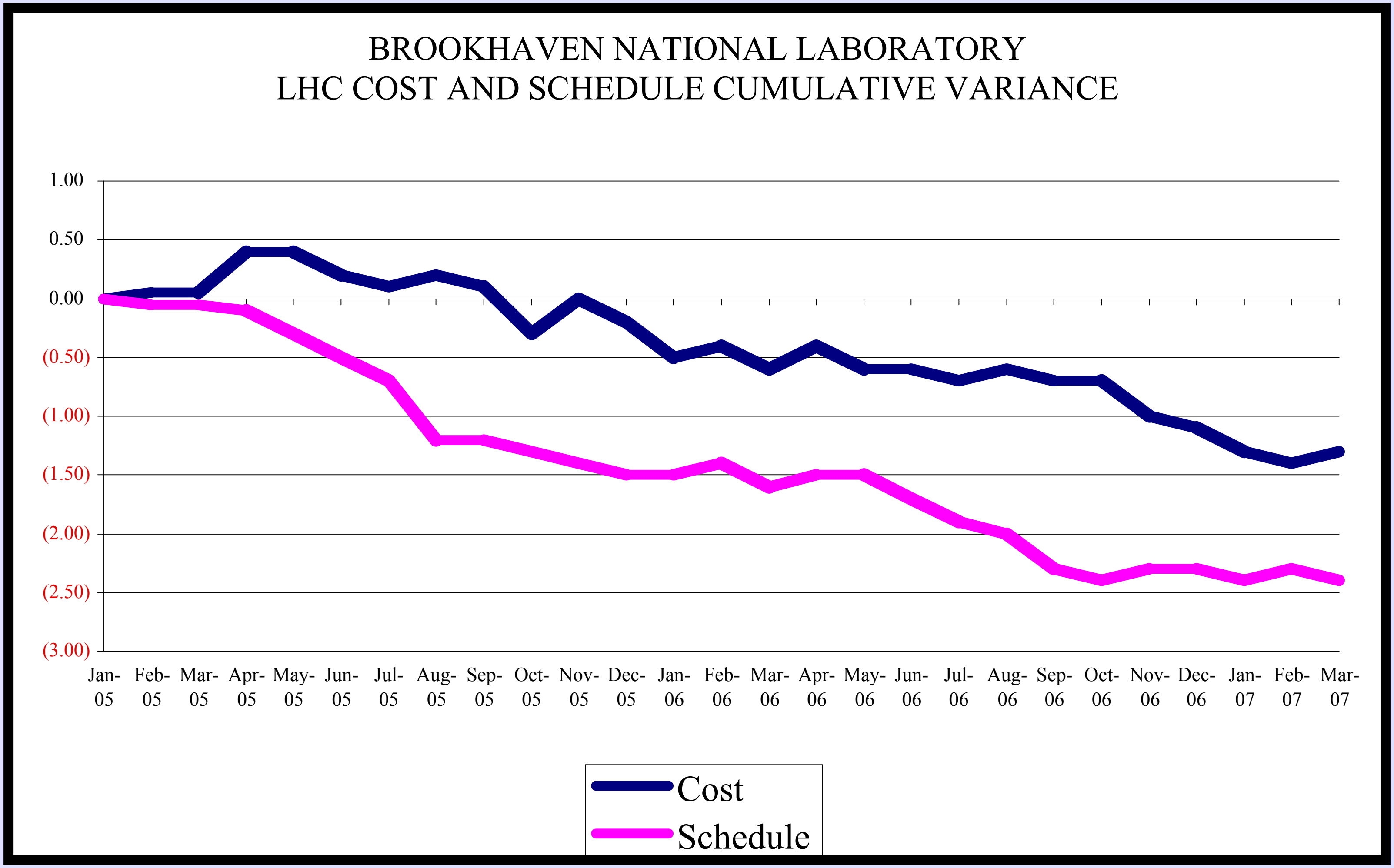
BNL LHC Magnet Production Status (cont'd)

- Remaining Schedule
  - Production
    - First D4 cold mass is welded, 2nd D4 is collared
    - D4's complete thru cryostatting by the end of May
    - D3 coils complete
    - D3 collaring started in March (collars & yokes in house)
    - D3 complete end of September
  - Testing
    - Still iterating a little on the exact details of the tests but at present the D2's should be complete (6) by the end of May
    - D4's by the end of Aug
    - D3's by the end of Dec
    - LHC MAC very strongly recommends cold testing all magnets. Proposal to CERN under consideration.

LHC Superconductor support: Samples Tested / Month



Cost & Schedule



Essentially all the cost variance is labour

Cost & Schedule: Recent cost pressures

- Delays with the D4 Laminations
- D1 survey and pipe re-positioning
- QQS changes
- D4 & D3 beam tube separation change
- Magnet Documentation volume
- Magnet Acceptance iterations
- "The magnet test from Hell" - D2L104 on the test stand for 3 months. Eventually revealed as oil contamination
- Shortage of cable to test
- Unit Costs ~5% high

Cost Containment

Costs are reviewed monthly:

- Individual WBS cost variances are analyzed
- Monthly meetings with central shops
- Labour charges reviewed monthly

Actions:

- Quench testing modified
- Cable testing scenario changed
- Magnet measurements modified
- Survey data minimized
- Helium losses mitigated
- Space charge rebate extended

LHC Construction: Conclusions

- Magnet production approaching completion
- Magnet acceptance & documentation proving non-trivial
- Field quality, quench levels good.
- Warm vs. cold testing not completely resolved
- Cable testing rate still somewhat low
- Continuous battle on costs and schedule

- LHC Accelerator Research Program (LARP) under definition

Magnet Division's Role In Future US HEP Projects

HEPAP's recent 20 year plan lists the *"absolutely central"* physics facilities as:

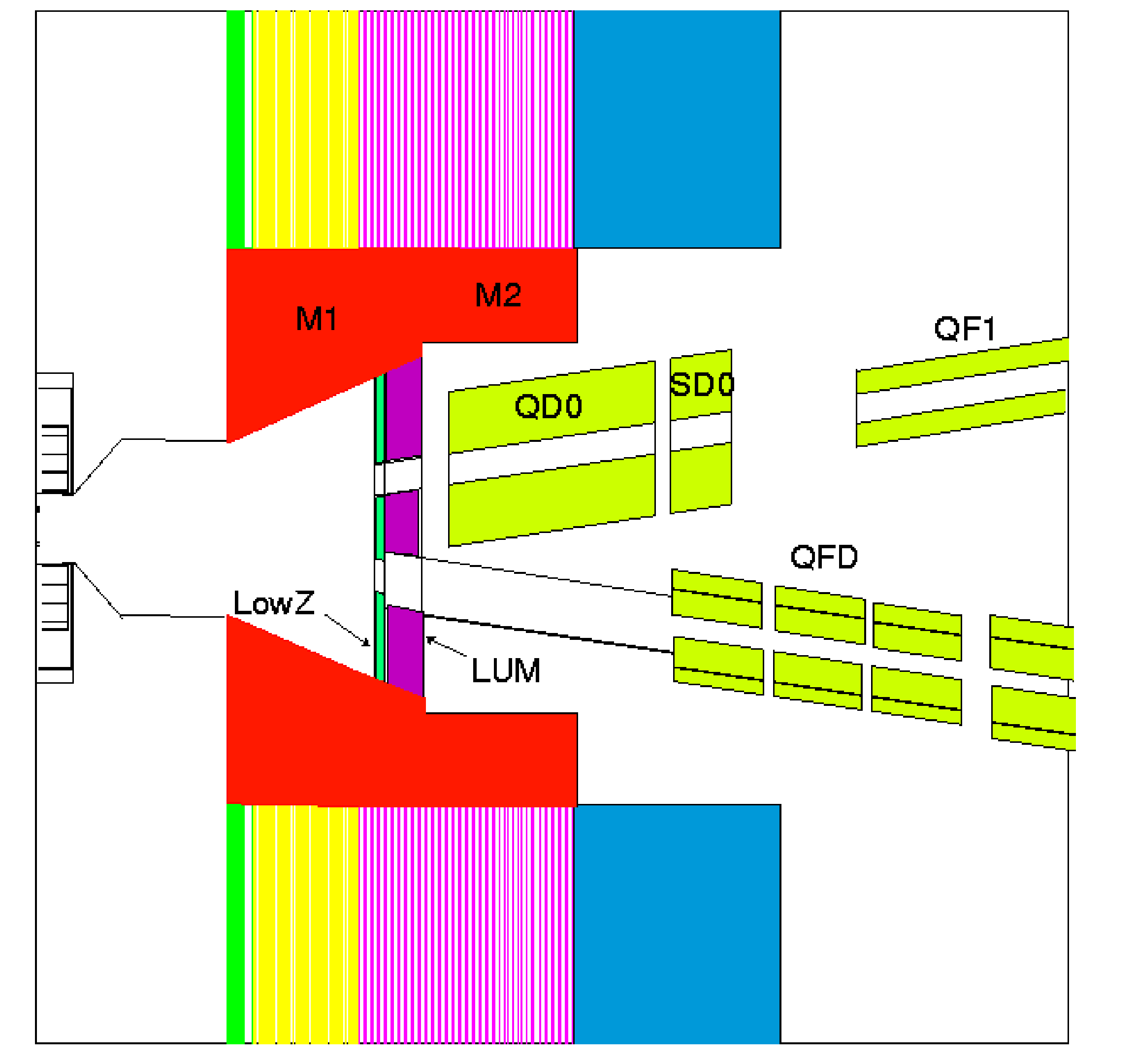
Linear Collider
LHC Luminosity upgrade
SNAP

The BNL Magnet Division is significantly involved in 2 of the 3, ergo we are strongly aligned with the goals of US HEP program.

Linear Collider: final focus /beam delivery system
Compact superconducting final focus quads + accelerator physics

LHC Upgrade: high performance IR's
Radiation resistant high field dipoles and quadrupoles

Linear Collider Final Focus - concept: highly compact superconducting quadrupoles for the final focus (and outgoing dump line)



Cold option gives flexibility: optics variation, energy variation, improved correction scheme, 20 mrad X-ing angle etc..

issues involve mechanical stability (1nm !), adjustability, interaction with the solenoid, field stability (5 ppm), radiation resistance and beam power (22 MW).

Outgoing beamline used for diagnostics & instrumentation

20mm incoming aperture

Linear Collider Physics Considerations

American Linear Collider Physics Group Executive Committee HEPAP report " Design Considerations for an International Linear Collider"

Higgs Production

- *"Higgs studies dictate: the ability to run at s = 90-500 Gev at luminosities commensurate with s scaling of the maximum energy luminosity"*

Running at the Z-pole & W+W- threshold

- *"The machine should be capable of some periodic running at the Z resonance. High statistics running at the Z or the W+W- threshold is desirable as an option"*
- *"A permanent magnet final quad system could severely restrict the frequency of collision energy changes" (Their italics)*

Post Collision diagnostics and $\gamma\gamma$ collisions

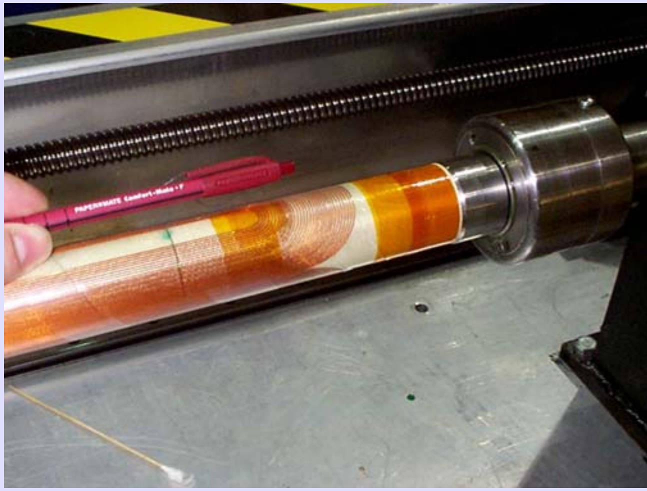
- *"The machine site should allow for the possibility of colliding beams with a small crossing angle"*

The Physics Program desires both energy flexibility and a crossing angle. The compact superconducting quadrupoles provides both

Linear Collider Final Focus Magnet Development

Assuming we can build the magnet (BNL LDRD)*: issues that look O.K.

- Field quality
- Field strength with operating margin
- Radiation damage and energy deposition (cold option has a 22 MW beam power !)
- Long term stability (feedback systems)



The problem would appear to be vibration. Ongoing work at SLAC would stabilize the cryostat. We will need to demonstrate that the field is stable if the cryostat is stable. We may be able to actually measure the magnetic field to this degree of accuracy. We would also try to measure (and if necessary stabilize) the relative motion of the cold mass and the cryostat. Since it is a non-iron magnet then the cold mass ought to represent the field accurately.

* Note that this technology (unique to BNL) has an interesting pedigree: SSC -> RHIC -> DESY -> BEPC II -> Linear Collider (?). This 20-year development cycle demonstrates how crucial it is to maintain and develop HEP technology.

Linear Collider Final Focus Magnet Development

We propose a 3 year R&D plan to build a prototype element and then demonstrate it meets the requirements + small (2-3 FTE) accelerator physics component based around the beam delivery system (end of Linac to the IP).

R&D Plan:

- Compare cryostat design options to minimize susceptibility to vibration
- Compare cooling schemes with respect to vibration (forced flow, pool boiling, pressurized superfluid, conduction)
- Evaluate mechanical interface (bellows, flex hose, straps, posts etc.) for the best passive isolation
- Build and measure prototype magnet
- Implement active seismic isolation of the cryostat
- Evaluate active isolation of the cold mass in the cryostat

Basic Cost:

– Design and construct prototype	\$2.5M
– Mechanical vibration R&D	3-4 FTE's (includes 1 post-doc) \$500K/yr materials \$400K
– Accelerator Physics	2-3 FTE's (includes 1 post-doc) \$400K/yr

Approximately \$2.5M/yr fully loaded for 3 years

LHC Luminosity Upgrades: LARP (LHC Accelerator Research Program) - BNL, Fermilab, LBL

Mechanism for on-going collaboration with CERN after the end of the construction project. Three areas of involvement: Machine upgrades (next generation IR's), accelerator physics, & next generation instrumentation. Encouraged by CERN to think luminosity not energy for upgrade scenarios

Magnet R&D for future IR's

- Large aperture quads (quadrupole first)
- Radiation resistant (high field) dipoles (both dipole and quadrupole first options)
- 2-in-1 high field dipoles (dipoles first)

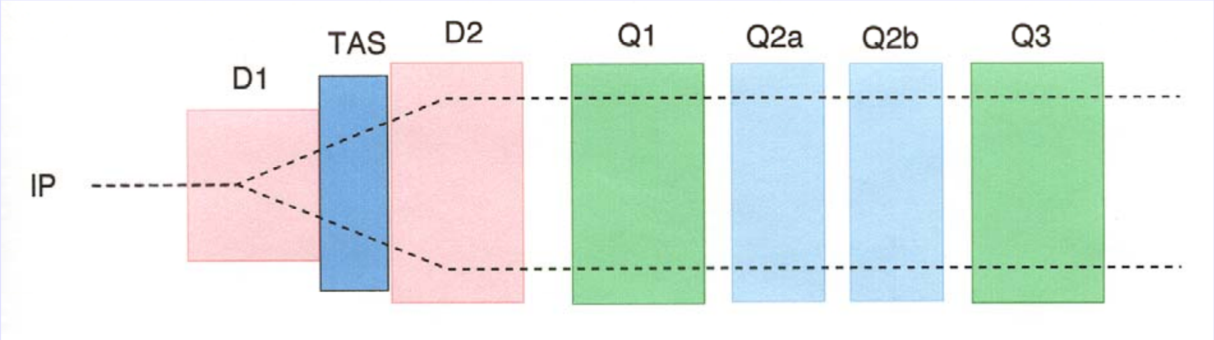
BNL is trying to look at the radiation resistant high field dipoles. (Possible follow on to some of the Muon Storage Ring work)

Accelerator Physics

Instrumentation

US effort in these areas is lead by Steve Peggs from BNL

LARP (LHC Accelerator Research Program) - BNL



Dipole first IR option helps if the luminosity is limited by the long range beam-beam interaction. BNL is indicating interest in the D1 dipole.

Technical Issues:

- High Fields (12-15T)
- Large Aperture (84 mm beam separation)
- Significant energy deposition from the IP (~1KW)
- Radiation damage

LARP Program review in July. The funding is slow in arriving and the program has experienced a 12 month delay. This is resulting in a "how do we get from here to there" problem.

High Field Magnet/Materials Program at BNL

- React & Wind R&D with ITER Nb_3Sn cable
  - Good results from both cable short sample and magnet tests
  - Test magnets reach short sample without any quench
- React & Wind R&D with High Performance Nb_3Sn cable
  - Poor performance observed in both cable and magnet tests
  - Program underway to find and eliminate the source(s) of degradation
- High Temperature Superconductor Cable Program
  - BNL measurements of Showa cable continue to show an upward trend
  - No significant degradation observed between cable & coil performance
- Specific Magnet Projects
  - Common coil 12 T "React & Wind" dipole for cable and insert coil tests
  - Beginning of LHC IR upgrade magnet design program

Magnet Division - Budget Summary

		FY02 actual	FY03 actual	FY04 request	FY04 president
KA11-02-04-1	LHC Construction	$7800K (41 FTE's)	$3300K (31 FTE's)	$1300K (10 FTE's)	$1300K (10 FTE's)
KA15-02-01-0	HEP R&D + SC materials development	$1010K (4.0 FTE's)	$990K (4.0 FTE's)	$1400K (5.0 FTE's)	$1000K (4.0 FTE's)
KA11-02-05-3	LARP	$100K (0.5 FTE's)	$140K (0.7 FTE's)	$400K (2.0 FTE's)	$200K (1.0 FTE's only 0.5 MD)
KA15-02-01-0	Linear Collider	$0	$0 (0 FTE's)	$2500K (10 FTE's)	$0 (0 FTE's)
	Total	$8910K 45.5 FTE's	$4330K 35.7 FTE's	$5600K 27 FTE's	$2500K 14.5 FTE's

BNL Superconducting Magnet R&D Facilities

- 5 Vertical Test Dewars (cold mass testing)
- 3 Horizontal test stations (full magnet testing)
- 2.5KW refrigerator complex (runs 365/24/7)
- Coil winding factory with 3 separate stations
- 2 Direct winding stations
- Superconductor test facility
- Coil and beam tube insulating station
- 3 magnet production lines (SNS, LHC, RHIC spares)
- 3 warm magnetic field measuring stations

Core Personnel Requirements
(FY03 w/o volume production capacity)

Superconductor materials development/test facility

3 Sci, 4 Techs -> 2 + 3

Magnetic structure design

3 Sci -> 3

Superconducting magnet fabrication

11 Design, 16 Mech Techs, 5 Mech Eng, 3 Q/A -> 9 + 12 + 5 + 1.5

Vertical and horizontal cryogenic testing

4 Cryo, 3 Techs, 1 Sci -> 4 + 3 + 1

Magnetic field measurements

2 Sci, 3 Techs -> 1 + 2

Electrical Support

3 E Eng, 2 Design, 12 Techs -> 3 + 1 + 9

Management/Admin/Computing/Safety/ ATLAS

6 Manage, 3 Admin, 3 Compute, 2 Safety, 3 ATLAS -> 5 + 2 + 3 + 1.5 + 2

Today 89 FTE's

Core 73 FTE's

Superconducting Magnet Division - Five year plan

- Critical mass personnel ~73 FTE'S. Below this level then we start to lose capability. The facility can only function in it's present form as an integrated unit.
- The HEP program would contain elements of:
  - Linear Collider development
  - LHC Project and Luminosity upgrade (LARP) program
  - HTS & Nb3Sn materials & magnet research
- Would like to produce a balance of HEP (25-30 FTE's), NP (25-30 FTE's), and other projects/work-for-others (20-30 FTE's)
- Continue to utilize strength in superconducting materials and direct wind technology as core capabilities.

Issues

- Magnet Division Staff reduction of 18-20 FTE's (25%) in October 04 projected based on FY04 Presidential (somewhat below the critical mass limit).
- Magnet R&D & Superconductor development at risk from reduced LHC facility support.
- The biggest issue will involve the Linear Collider work. It is obviously not possible to develop a meaningful program without funding. It is also disingenuous to pretend otherwise. It appears that our proposed technical approach to the final focus is becoming accepted as potentially the only viable solution. It would be disappointing (and presumably counter productive) if we are unable to pursue this.

Superconducting Magnet Division HEP Program - Summary

- LHC construction activities will be completed within calendar 03. Technical performance fine, cost pressures evident.
- Future program well aligned with national HEP goals
- LARP Program funding continues to fall below guidance and has effectively experienced a one year delay
- It is important for us to recognize that a Linear Collider program needs to involve all of the major HEP labs in the US to be successful. BNL can make a significant contribution to this effort.
- Need HEP support for 25-30 FTE's and $5-6M to achieve these goals